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Nanomechanical Infrared Spectroscopy with completely free-standing pyrolytic carbon string resonators for paracetamol detection

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Here, we present a nanomechanical Infrared (NAM-IR) Spectroscopy for detection of paracetamol by using pyrolytic carbon string resonators. The string resonators were fabricated by pyrolysis process of SU-8 in inert atmosphere and followed by characterization using optical readout to measure the resonance frequencies and quality factors. Paracetamol deposited on the resonators converts absorbed IR light into a measurable frequency detuning of the string through photothermal heating. The resulting frequency change was tracked to obtain the absorption spectrum of paracetamol.

In the past few decades, Carbon Micro Electro-Mechanical Systems (C-MEMS) sensors have become increasingly attractive for a wide range of applications especially in electrochemical sensors [1, 2]. In C-MEMS, photoresist is patterned by photolithography then followed by the pyrolyzed at high temperatures in an inert atmosphere. Pyrolytic carbon shows promising potential such as conductive and controllable properties for fabricating MEMS sensors. In our previous work, pyrolytic carbon string resonators were optimized [3]. However, the gap between the strings and the underlying substrate was very small and the proximity of the substrate made it impossible to deposit and analyse samples such as micro particles. Also, the IR measurements with a laser require optical access from the backside of the substrate. Therefore, new pyrolytic carbon string resonators fully separated from the substrate and placed over a through-wafer hole were fabricated.

In this work, fully free-standing pyrolytic carbon string resonators (length 400 µm, width 30 µm, thickness 700 nm) were used as mass sensor to detect the amount of deposited paracetamol by tracking the resonance frequency shift of the resonators. Additionally, the NAM-IR spectrum was used for identifying the paracetamol. Figure 1 shows the SEM image of the fabricated pyrolytic carbon string resonators. Paracetamol was diluted in isopropanol and sprayed on top of the pyrolytic carbon string resonators (Figure 2). The resonators were characterized before and after the drug deposition to monitor the change of resonance frequency. From the shift of resonance frequency the amount of drug will be determined. Figure 3 shows that the resonance frequency depends on conditions of the paracetamol deposition.

For identifying the paracetamol, NAM-IR data was collected to obtain the spectrum of pyrolytic carbon string resonators before and after deposition of paracetamol. Because of photothermal heating, IR light absorbed by the paracetamol is converted into a measurable frequency detuning of the string resonator. A NAM-IR spectrum is thus readily obtained by recording this photothermal frequency detuning of the resonator. The results (Figure 4) show that some characteristic peaks (805, 835, 1500, 1555 cm^{-1}) for paracetamol appeared in the spectrum (red circles). Those peaks were compared with a reference IR spectrum of paracetamol which confirmed the appearance of paracetamol on top of the pyrolytic carbon string resonators.

In conclusion, fully released pyrolytic carbon string resonators were used as dual sensors for detection of drug. First, they were applied as a mass sensor to obtain the amount of paracetamol which was deposited on top of the string by spray coating method. In parallel, the NAM-IR spectroscopy method was used for identifying the paracetamol. These results confirm that the pyrolytic carbon string resonators are potential sensors for drug characterization and detection.

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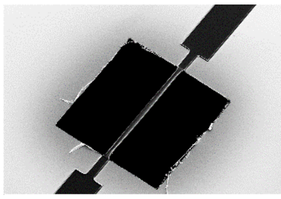

Figure 1. SEM image of free-standing pyrolytic carbon string resonator.

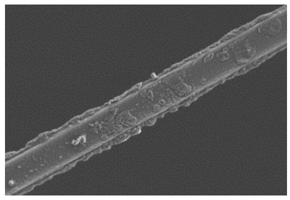

Figure 2. SEM image of pyrolytic carbon with paracetamol.

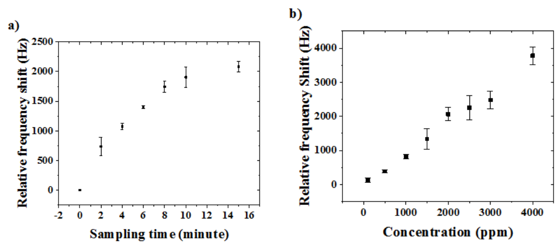

Figure 3. Resonance frequency shift of free-standing pyrolytic carbon string resonators depending on (a) deposition time and (b) concentration of paracetamol.

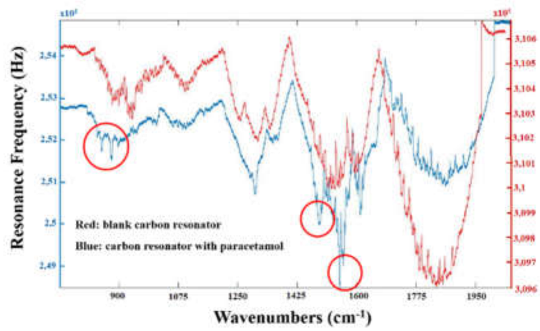

Figure 4. NAM-IR spectrum of (red) pyrolytic carbon string and (blue) pyrolytic carbon string with paracetamol.